# Energy Efficiency
# Lessons and Plans from California

## Delhi & Mumbai
## March 2009

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**http://www.energy.ca.gov/commissioners/rosenfeld.html**

**or just Google “Art Rosenfeld”**

# *Does Anyone See A Problem With This Picture?*

# Two Energy Agencies in California

- The California Public Utilities Commission (CPUC) was formed in 1890 to regulate natural monopolies, like railroads, and later electric and gas utilities.
- The California Energy Commission (CEC) was formed in 1974 to regulate the environmental side of energy production and use.
- Now the two agencies work very closely, particularly to delay climate change.
- The Investor-Owned Utilities, under the guidance of the CPUC, spend “Public Goods Charge” money (rate-payer money) to do everything they can that is cost effective to beat existing standards.
- The Publicly-Owned utilities (20% of the power), under loose supervision by the CEC, do the same.

# California Energy Commission Responsibilities

## Both Regulation and R&D

- California Building and Appliance Standards
  - Started 1977
  - Updated every few years
- Siting Thermal Power Plants Larger than 50 MW
- Forecasting Supply and Demand (electricity and fuels)
- Research and Development
  - ~ $80 million per year
- CPUC & CEC are collaborating to introduce communicating electric meters and thermostats that are programmable to respond to time-dependent electric tariffs.

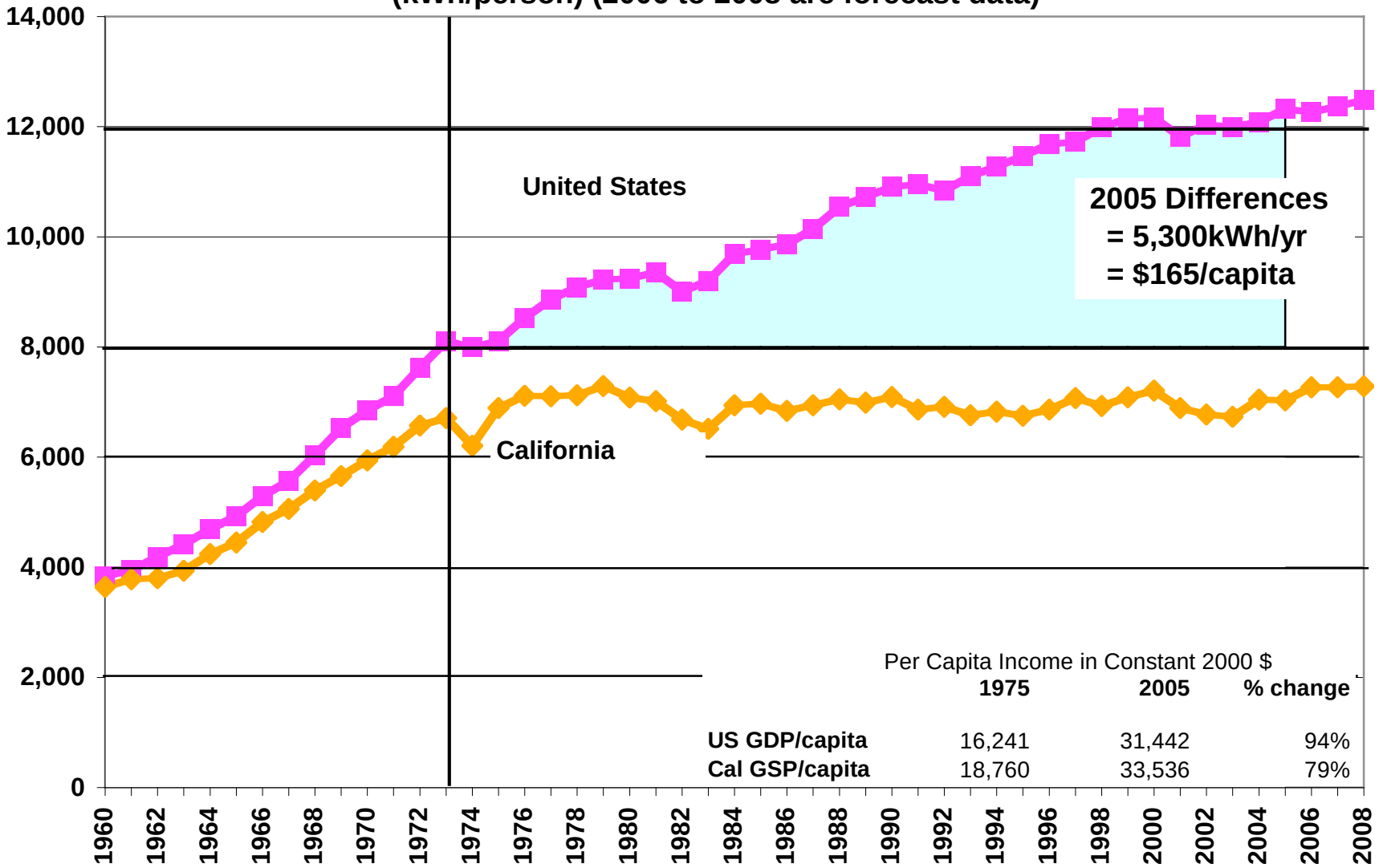
# California's Energy Action Plan

- California's Energy Agencies first adopted an Energy Action Plan in 2003. Central to this is the State's preferred "Loading Order" for resource expansion.

- 1. Energy efficiency and Demand Response
- 2. Renewable Generation,
- 3. Increased development of affordable & reliable conventional generation
- 4. Transmission expansion to support all of California's energy goals.

- The Energy Action Plan has been updated since 2003 and provides overall policy direction to the various state agencies involved with the energy sectors

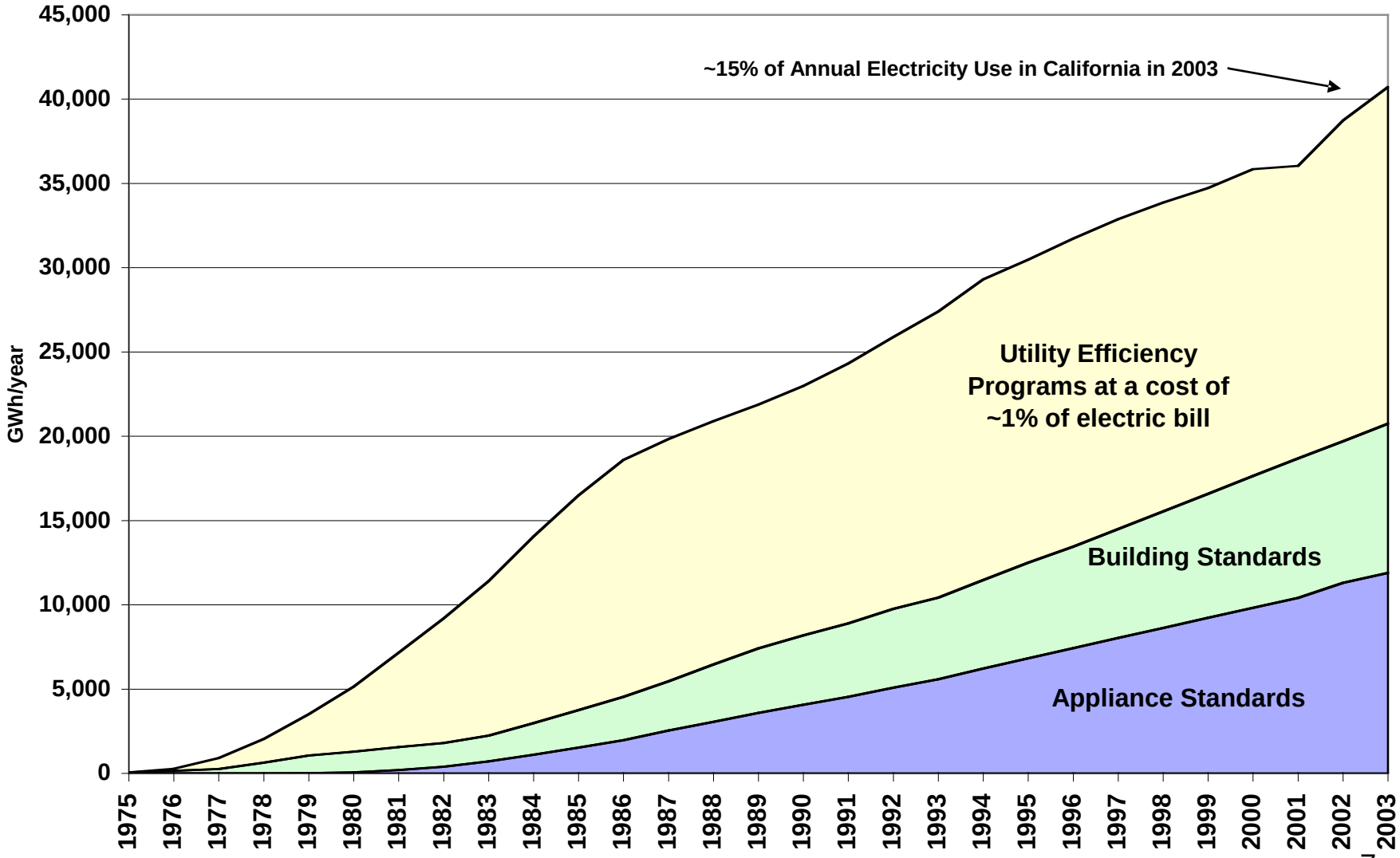
## Per Capita Electricity Sales (not including self-generation) (kWh/person) (2006 to 2008 are forecast data)

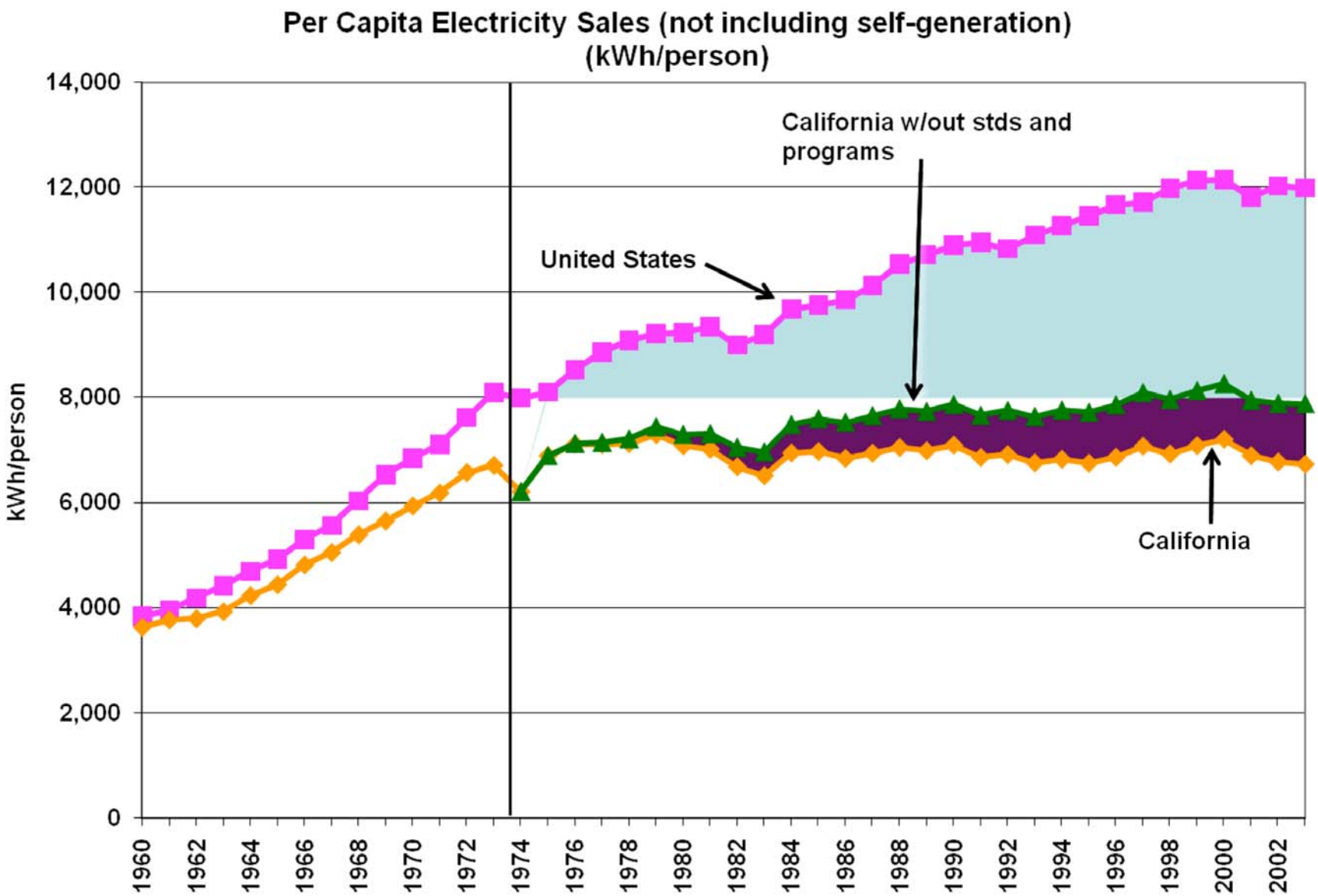



Per Capita Income in Constant 2000 $

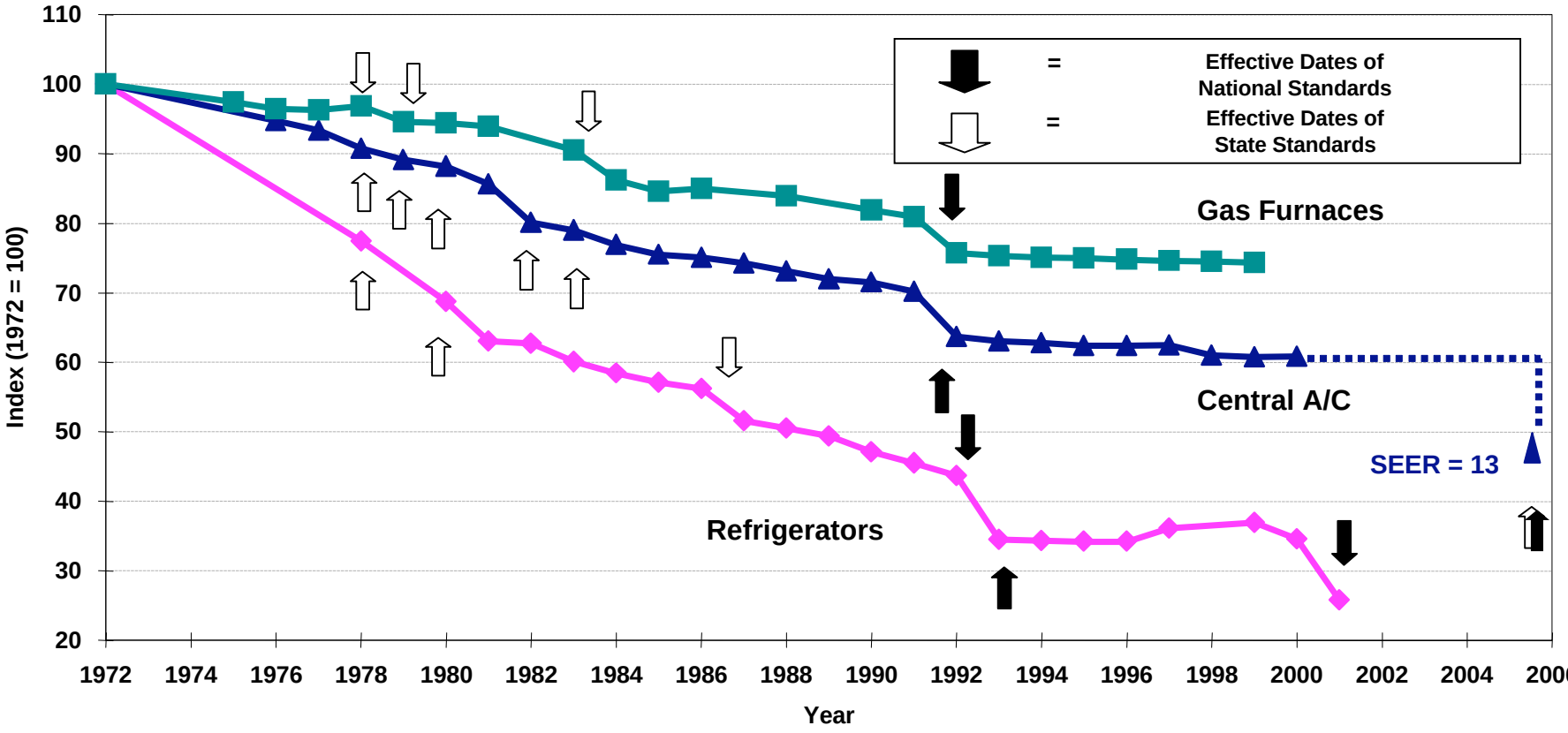
| | 1975 | 2005 | % change |
|---|---|---|---|
| US GDP/capita | 16,241 | 31,442 | 94% |
| Cal GSP/capita | 18,760 | 33,536 | 79% |

## Annual Energy Savings from Efficiency Programs and Standards



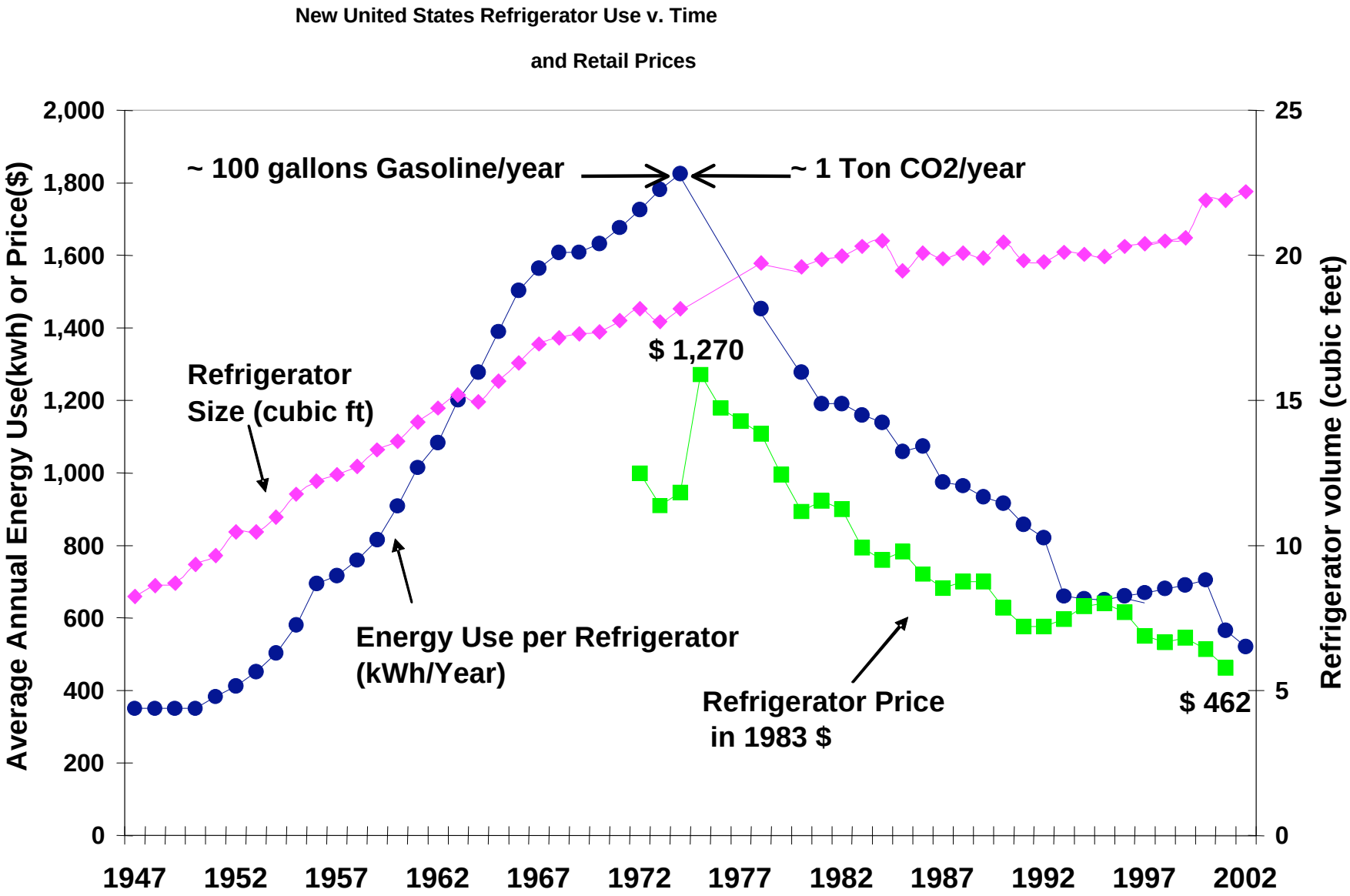

Per Capita Electricity Sales (not including self-generation)
(kWh/person)
kWh/person
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
California w/out stds and programs
United States
California

# Impact of Standards on Efficiency of 3 Appliances



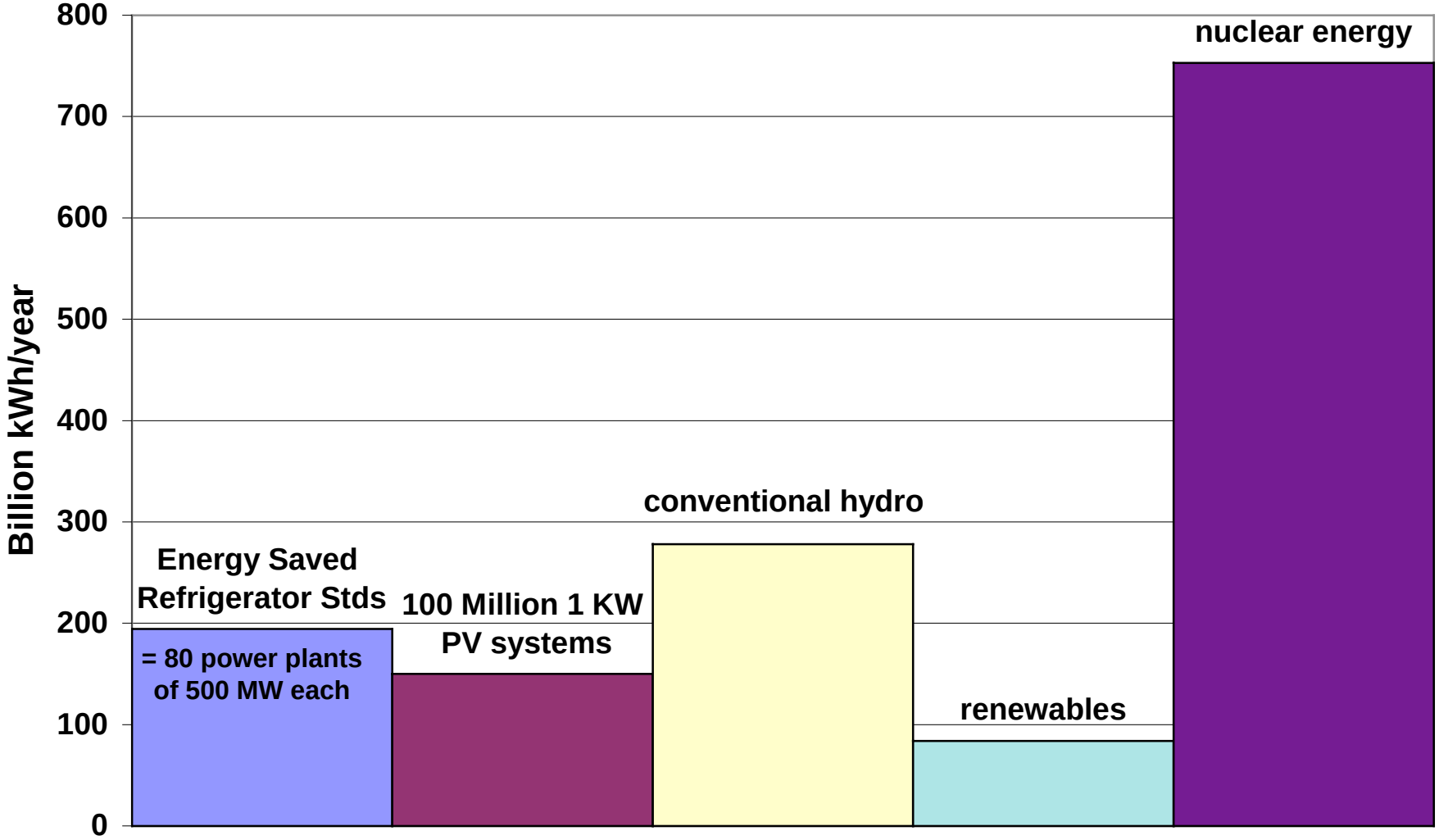

Source: S. Nadel, ACEEE,

in ECEEE 2003 Summer Study, www.eceee.org



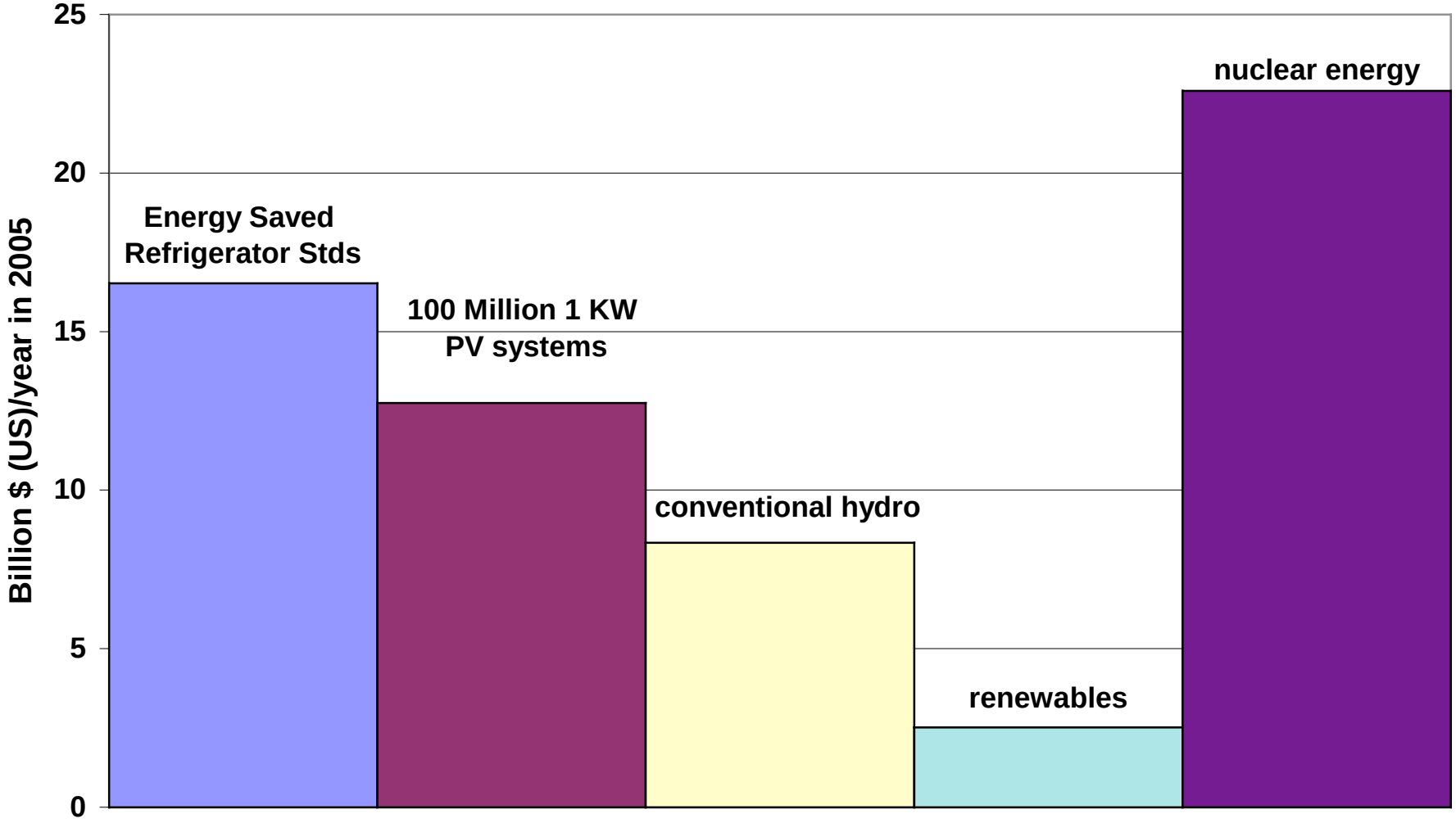

Source: David Goldstein

## Annual Energy Saved vs. Several Sources of Supply In the United States

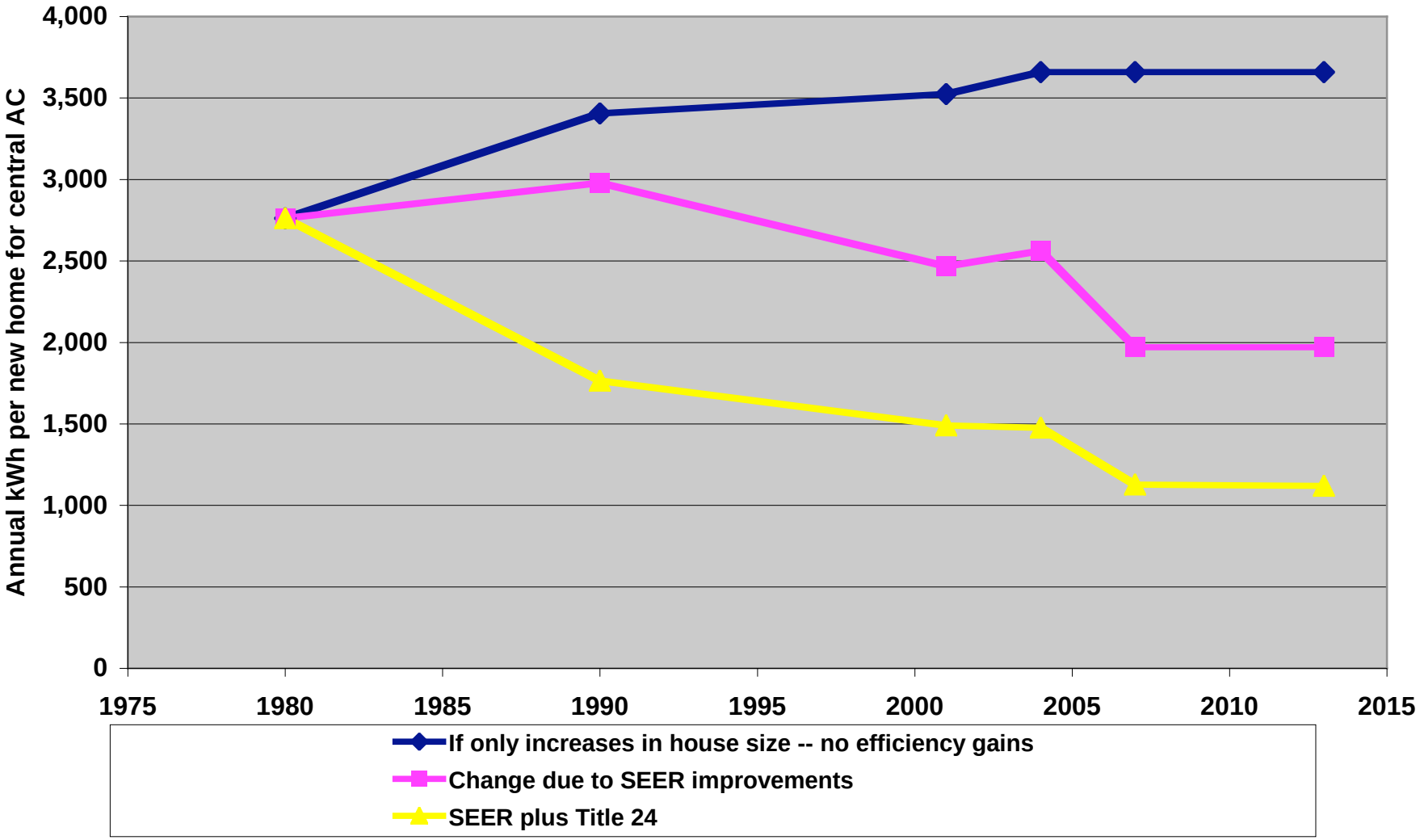


## In the United States

## Value of Energy to be Saved (at 8.5 cents/kWh, retail price) vs. Several Sources of Supply in 2005 (at 3 cents/kWh, wholesale price)

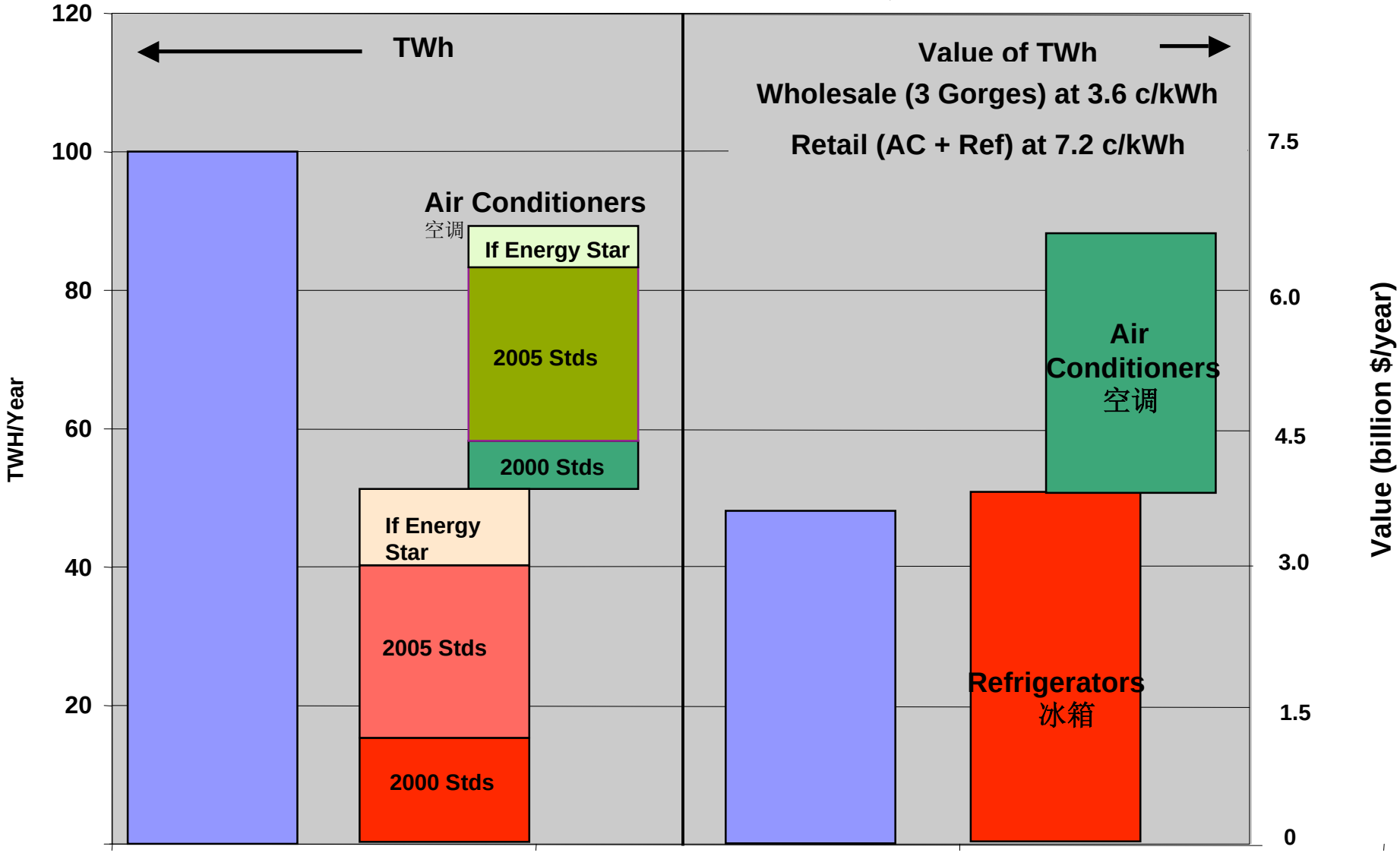


## Air Conditioning Energy Use in Single Family Homes in PG&E
## The effect of AC Standards (SEER) and Title 24 standards



# Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

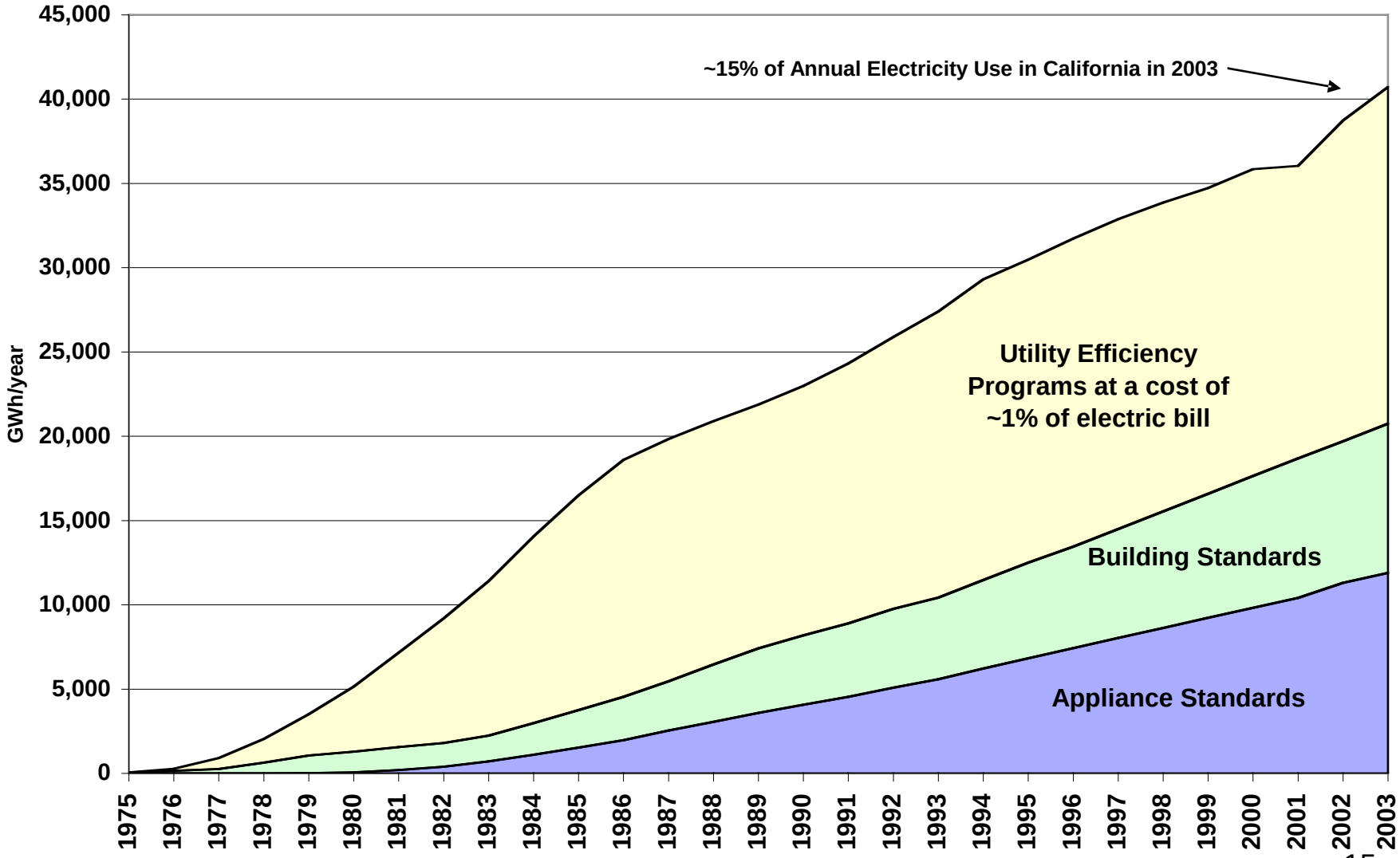
# 三峡电量与电冰箱、空调能效对比



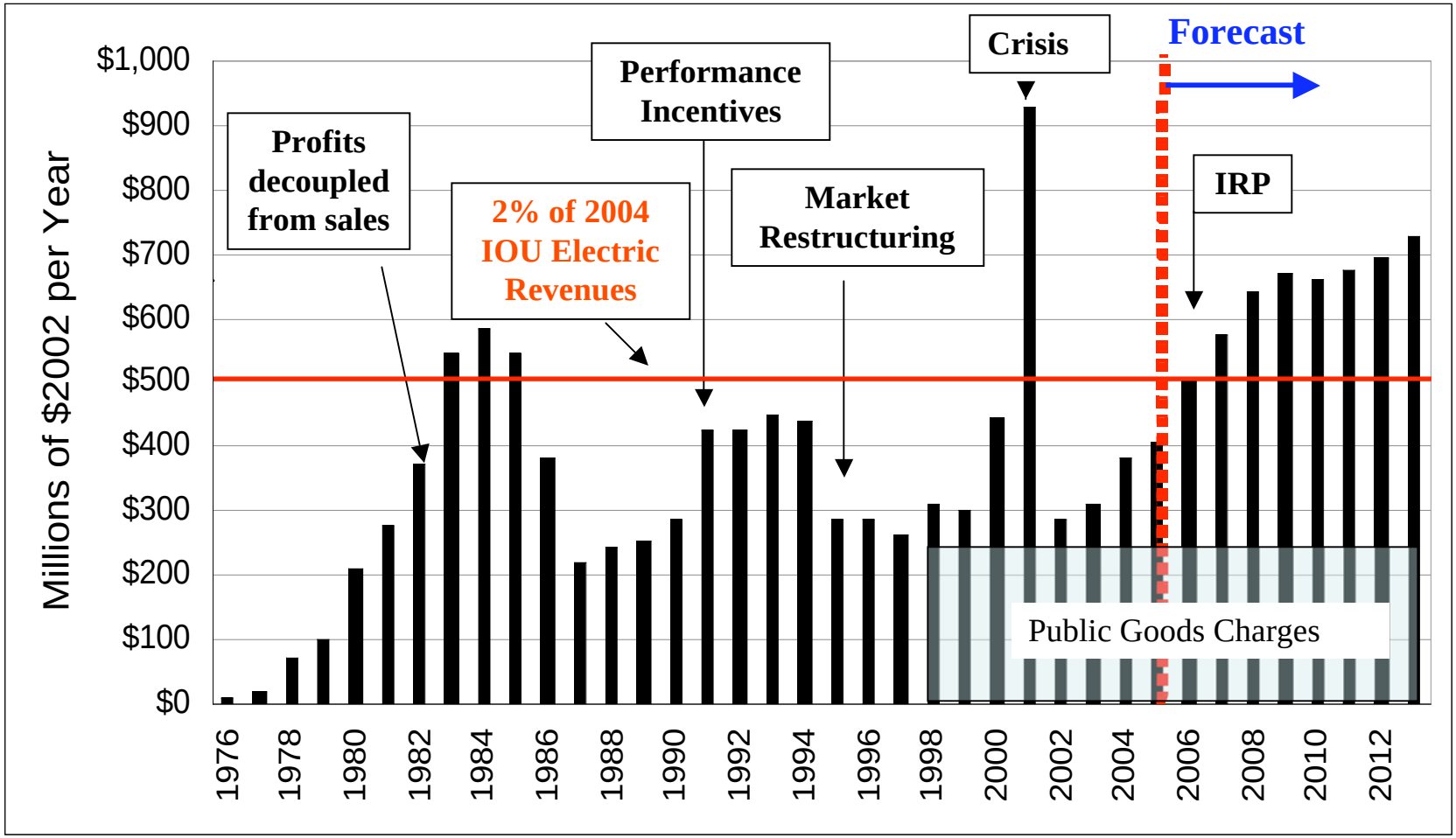

Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL

标准生效后，10年节约电量

## Annual Energy Savings from Efficiency Programs and Standards

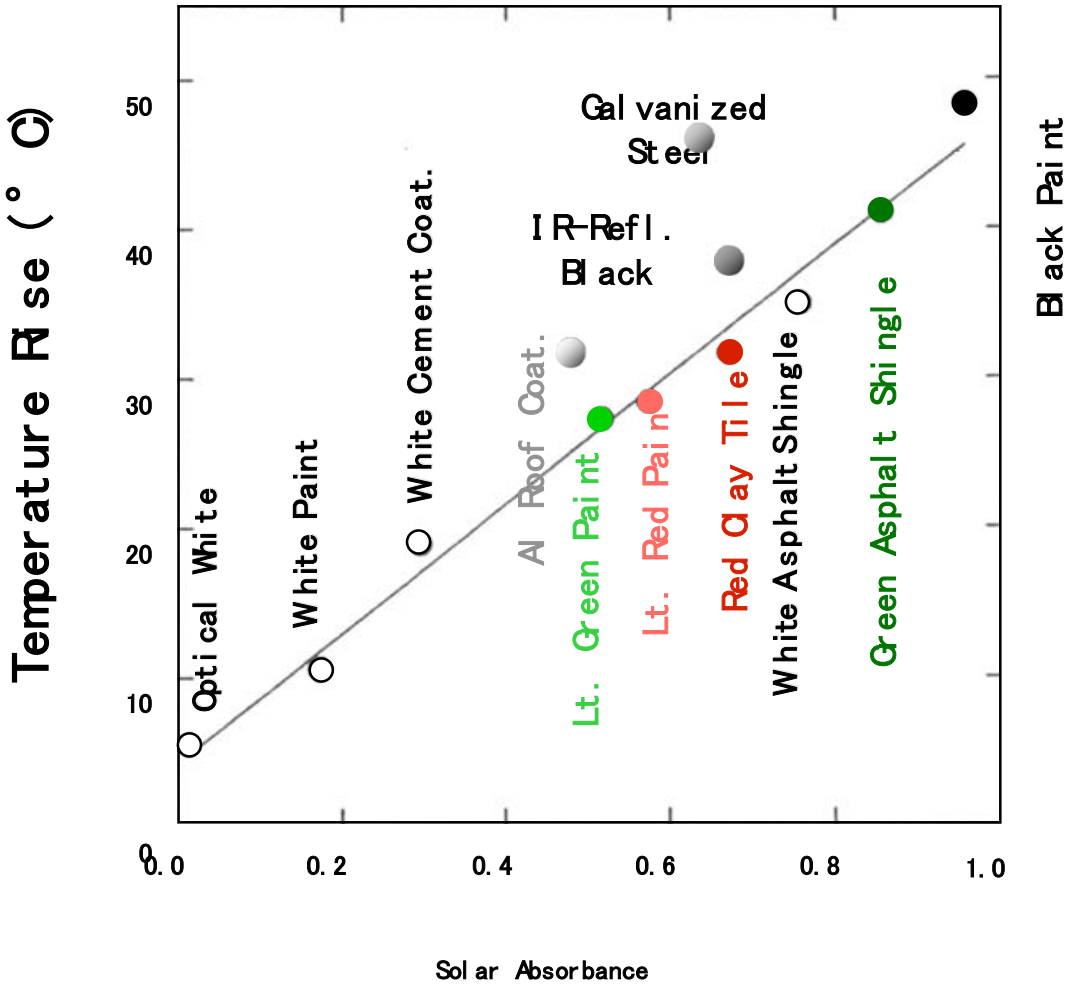


# California IOU's Investment in Energy Efficiency



# White Roofs

# Temperature Rise of Various Materials in Sunlight



# White is ‘cool’ in Bermuda

# and in Santorini, Greece

# and in Hyderabad, India

# Cool Roof Technologies

**Old**

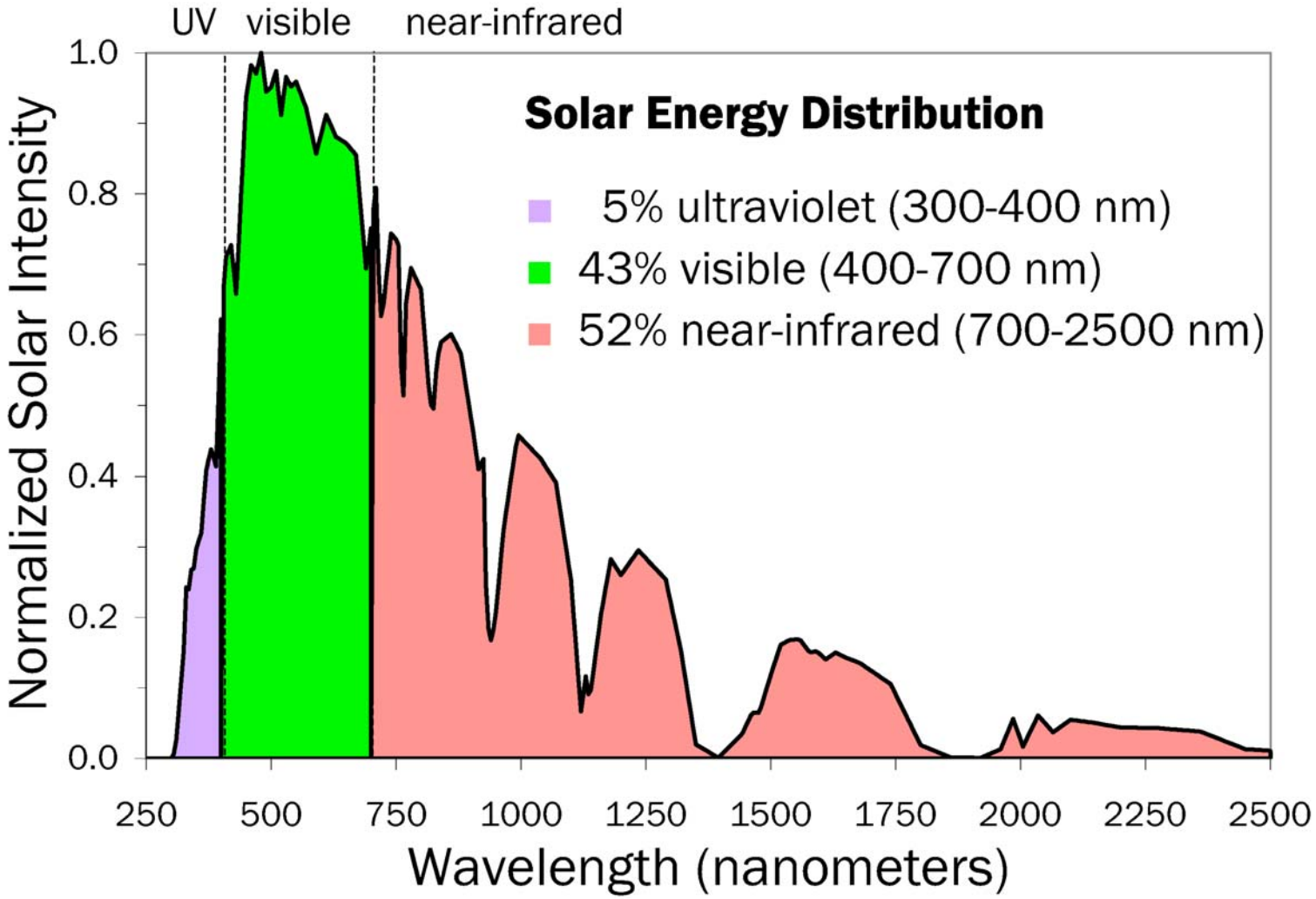
flat, white

pitched, white

**New**

pitched, cool & colored

# Cool Colors Reflect Invisible Near-Infrared Sunlight



# White Roofs

- In California and a growing number of US states, white roofs are required for new buildings, and re-roofing to reduce air conditioning load and “smog”($O_3$).

- But a new concept is that white roofs also cool the world directly.

# Effect of Solar Reflective Roofs and Pavements in Cooling the Globe

**(Source: Akbari, Menon, Rosenfeld. *Climatic Change*, 2008)**

| | Δ Solar Reflectivity | $CO_2$ Offset by 100 $m^2$ | $CO_2$ Offset Globally |
|---|---|---|---|
| White Roof | 0.40 | 10 tons | |
| Average Roof* | 0.25 | 6.3 tons** | 24 Gt |
| Cool Pavement | 0.15 | 4 tons | 20 Gt |
| Total Potential | | | 44 Gt |
| Value of 44 Gt $CO_2$ at $25/t ~ $1 Trillion | | | |

*** White Roof will be "diluted" by cool colored roofs of lower reflectivity, and roofs that can not be changed, because they are long-lived tile, or perhaps they are already white.**

**** Compare 10 tons with a family car, which emits ~4 tons/year.**

# $CO_2$ Equivalency of Cool Roofs World-wide (Tropics+Temperate)

- Cool Roofs alone offset 24 Gt CO2
- Worth > €600 Billion
- To Convert 24 Gt CO2 one time into a rate
- Assume 20 Year Program, thus

1.2 Gt CO2/year

- Average World Car Emits 4 tCO2/year,

**equivalent to 300 Million Cars off the Road for 20 years.**

# Akbari et al. Main Finding


**100 $m^2$ of a white roof, replacing a dark roof, offset the emission of 10 tons of $CO_2$**

- *To be published in Climatic Change 2008.*

# • Global Cooling: Increasing World-wide Urban Albedos to Offset CO2

July 28, 2008

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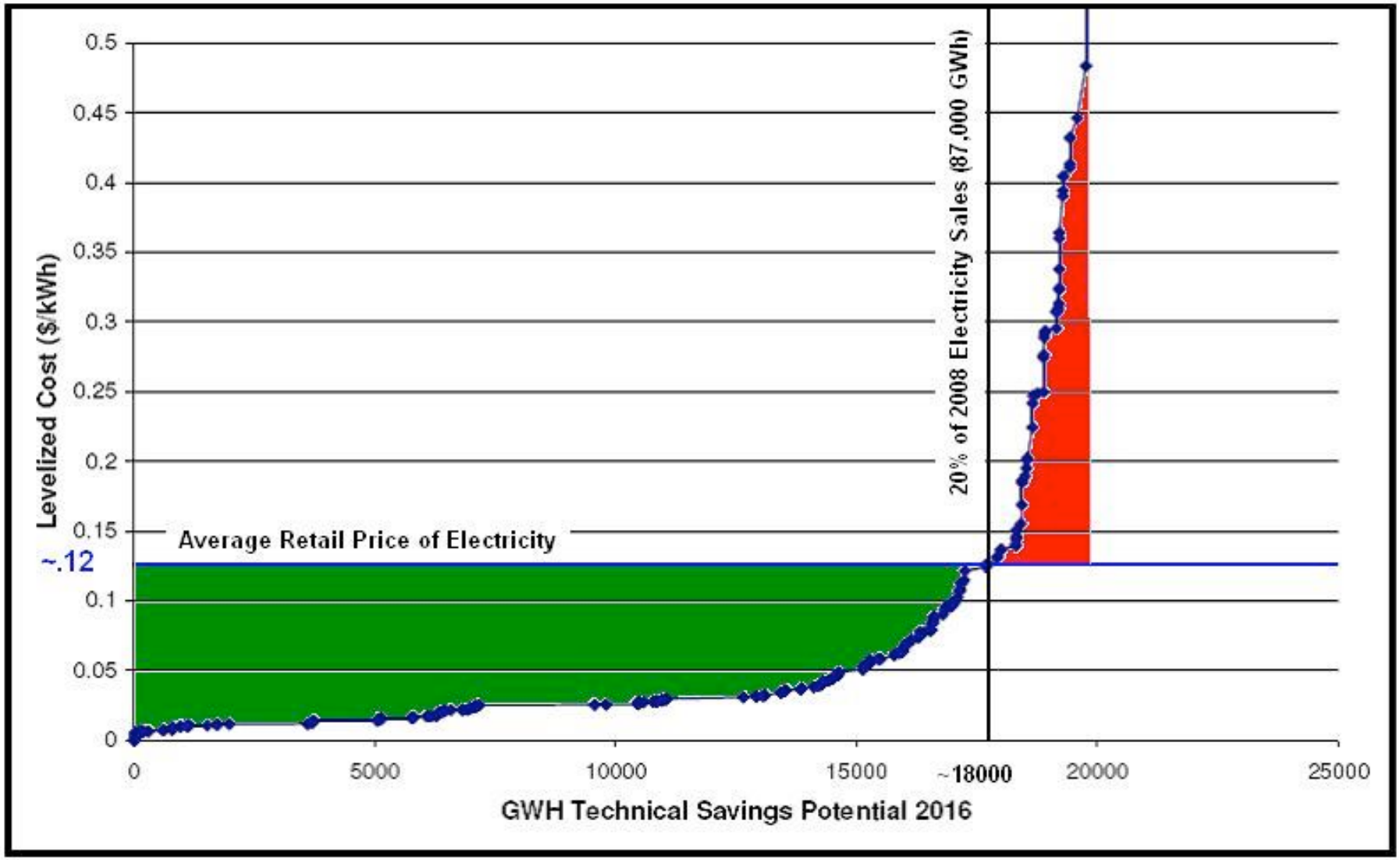
# • A First Step In Geo-Engineering Which Saves Money and Has Known Positive Environmental Impacts

# Conservation Supply Curves and Carbon Abatement Curves

## PG&E Electric Supply Curve

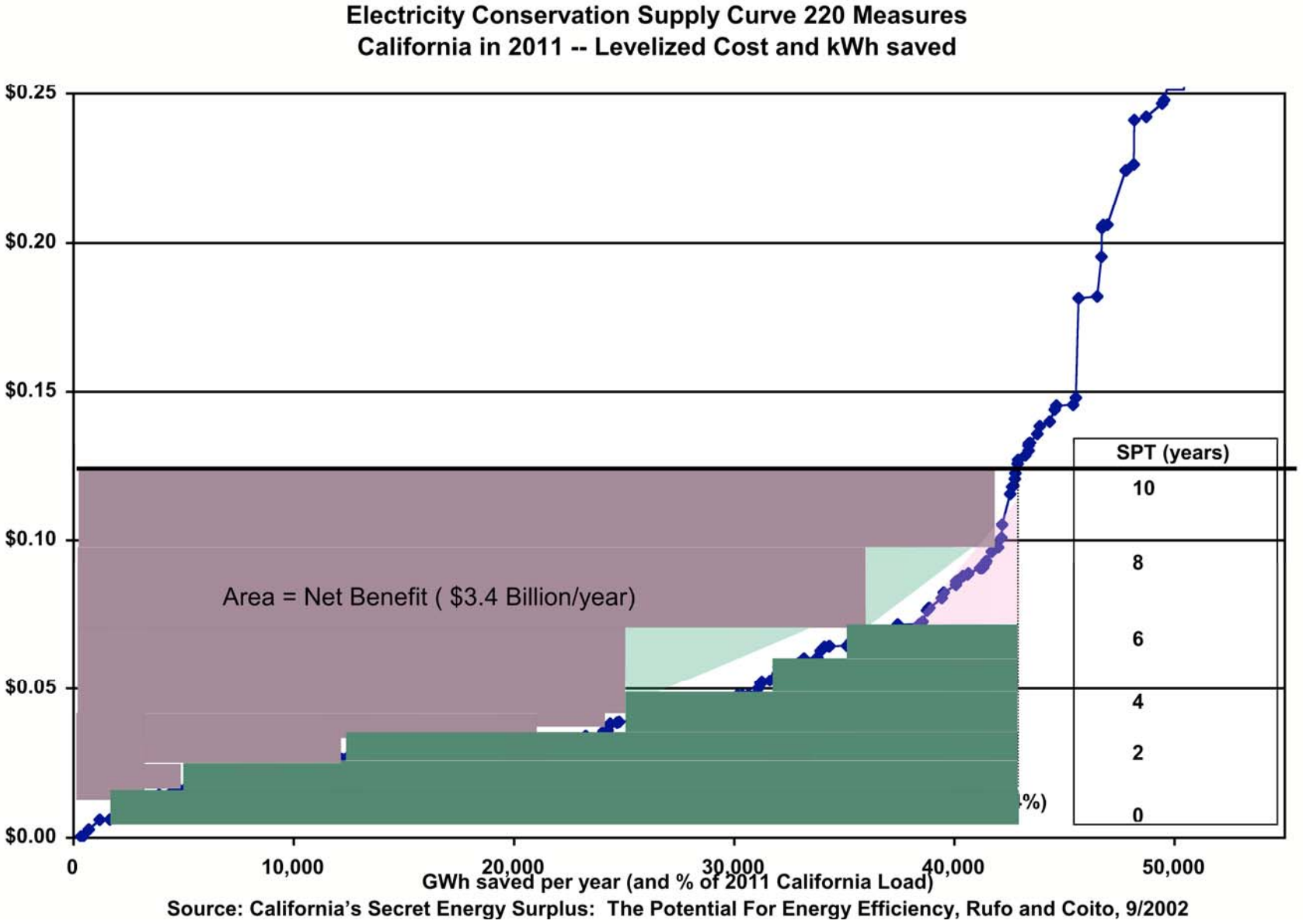


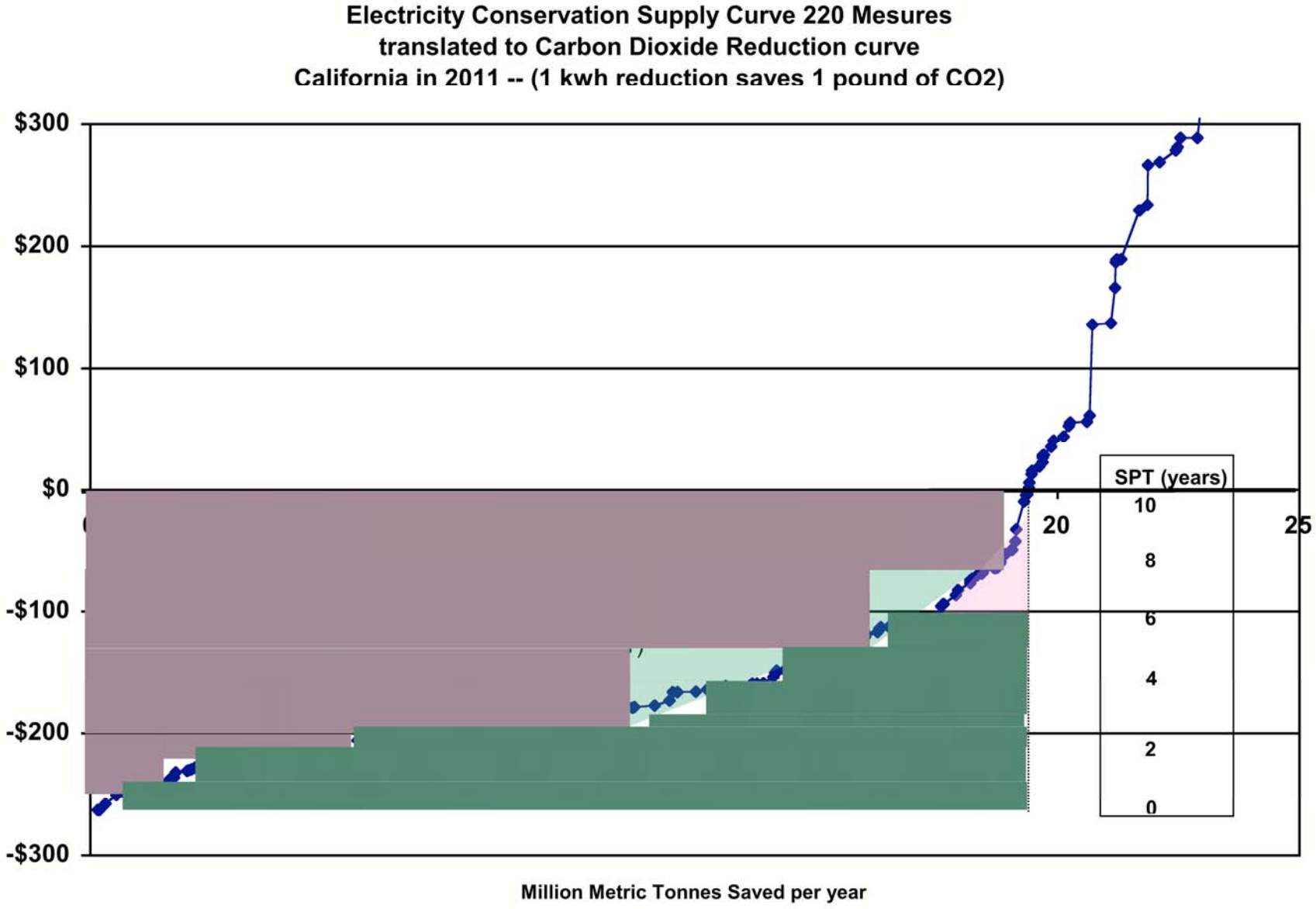

Source: Itron Inc and KEMA Inc, California Energy Efficiency Potential Study, ( Prepared for Pacific Gas and Electric company (September 2008)

# PG&E Electric Supply Curve
# Summary of Previous Slide

- 200 Projects costing at or below 12 cents /kWh average retail price
- Total Potential Savings of 18,000 GWh for these projects
- This represents about 20% of total electric sales for PG&E in 2008

| Technology | Sector | Levelized Supply Cost | Levelized Supply Cost with Programs | Technical GWH 2016 |
|---|---|---|---|---|
| S04_0515 | INC | 0 | 0.005 | 4.549 |
| S01_0515 | INC | 0 | 0.005 | 13.356 |
| WWT_PDW | INC | 0.002 | 0.007 | 0.08 |
| CRm_ExOp | INC | 0.005 | 0.01 | 0.41 |
| CRm_HECh | INC | 0.005 | 0.01 | 4.52 |
| S36_HEVC | INC | 0.005 | 0.01 | 0.729 |
| Fans_ASD_(6-100_hp) | Existing Industrial | 0.005 | 0.012 | 27.33 |
| Comp_Air_ASD_(6-100_hp) | Existing Industrial | 0.005 | 0.012 | 31.33 |
| Pumps_ASD_(6-100_hp) | Existing Industrial | 0.005 | 0.012 | 54.46 |
| CRm_UAS | INC | 0.005 | 0.01 | 3.01 |
| WWT_Des | INC | 0.006 | 0.011 | 1.83 |
| CRm_POHP | INC | 0.006 | 0.011 | 1.31 |
| CRm_PrPl | INC | 0.006 | 0.011 | 3.75 |
| CRm_EfFS | INC | 0.006 | 0.011 | 2.02 |
| Fans_OM | Existing Industrial | 0.006 | 0.014 | 11.94 |
| Compressed_AirSizing | Existing Industrial | 0.006 | 0.014 | 49.29 |
| Pumps_OM | Existing Industrial | 0.006 | 0.014 | 95.2 |
| C_CFL_Over24W | Existing Commercial | 0.007 | 0.035 | 305.09 |
| CRm_PACR | INC | 0.007 | 0.012 | 7.89 |
| Compressed_Air-OM | Existing Industrial | 0.008 | 0.015 | 172.52 |
| CRm_VACS | INC | 0.008 | 0.013 | 1.45 |
| S36_ACrS | INC | 0.008 | 0.013 | 1.16 |
| CRm_LPDF | INC | 0.008 | 0.013 | 2.43 |
| WWT_VFD | INC | 0.008 | 0.013 | 12.4 |
| S04_0510 | INC | 0.008 | 0.013 | 0 |
| CRm_PrPm | INC | 0.009 | 0.014 | 0.42 |
| CRm_PMEV | INC | 0.009 | 0.014 | 0.3 |
| CRm_PMEW | INC | 0.009 | 0.014 | 0.21 |
| C_CFL_Under15W | Existing Commercial | 0.009 | 0.04 | 151.16 |
| C_T12_Delamping_4Ft | Existing Commercial | 0.021 | 0.027 | 123.76 |
| C_Ref_EvapFan_ECM | Existing Commercial | 0.022 | 0.027 | 238.21 |


Electricity Conservation Supply Curve 220 Measures
California in 2011 -- Levelized Cost and kWh saved
$0.25
$0.20
$0.15
$0.10
$0.05
$0.00
Area = Net Benefit ( $3.4 Billion/year)
SPT (years)
10
8
6
4
2
0
0
10,000
20,000
30,000
40,000
50,000
GWh saved per year (and % of 2011 California Load)
Source: California's Secret Energy Surplus: The Potential For Energy Efficiency, Rufo and Coito, 9/2002


Electricity Conservation Supply Curve 220 Mesures
translated to Carbon Dioxide Reduction curve
California in 2011 -- (1 kwh reduction saves 1 pound of CO2)
$300
$200
$100
$0
-$100
-$200
-$300
20
25
SPT (years)
10
8
6
4
2
0
Million Metric Tonnes Saved per year

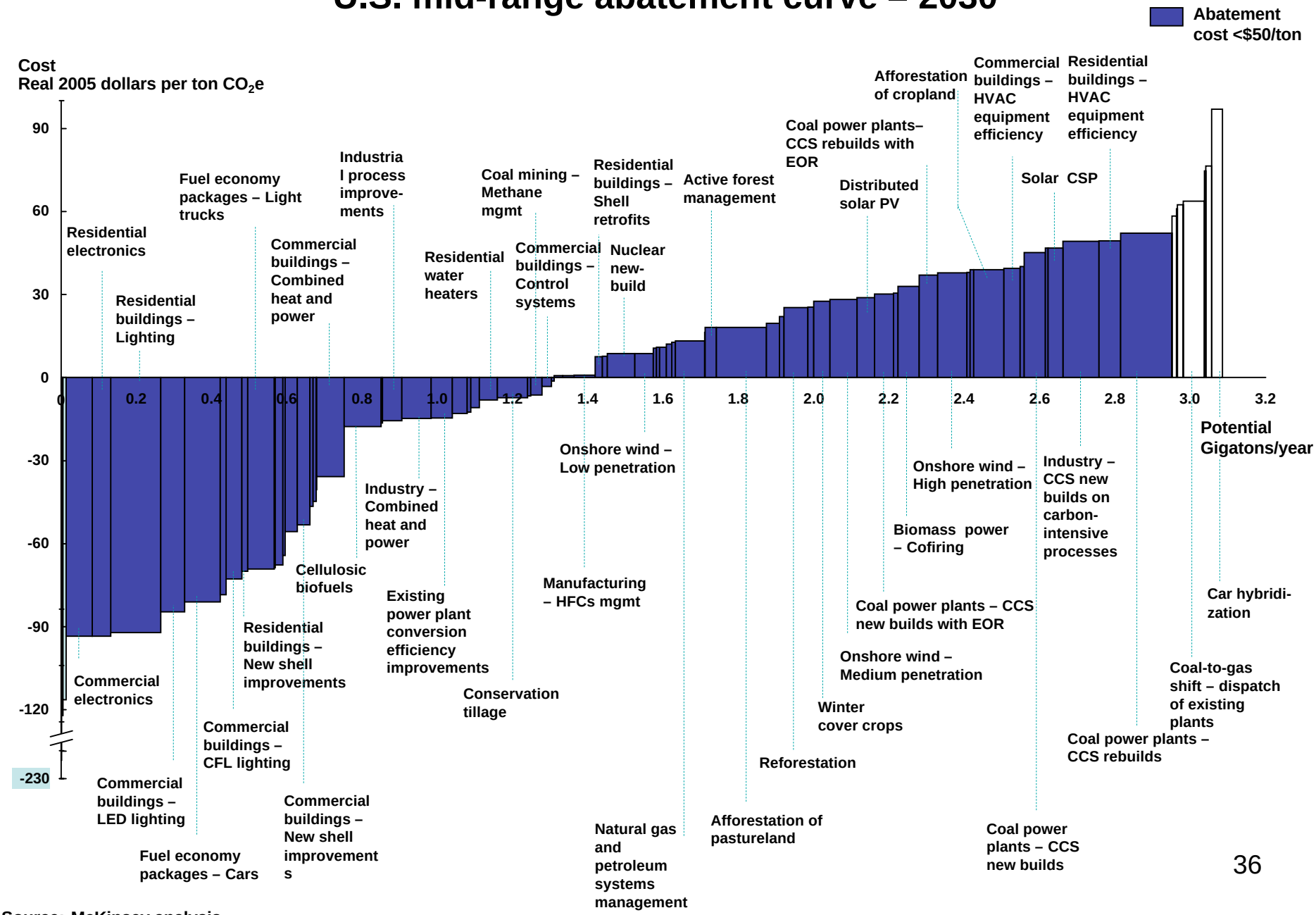
# Reducing U.S. Greenhouse Gas Emissions: *How Much at What Cost?*

**US Greenhouse Gas Abatement Mapping Initiative**

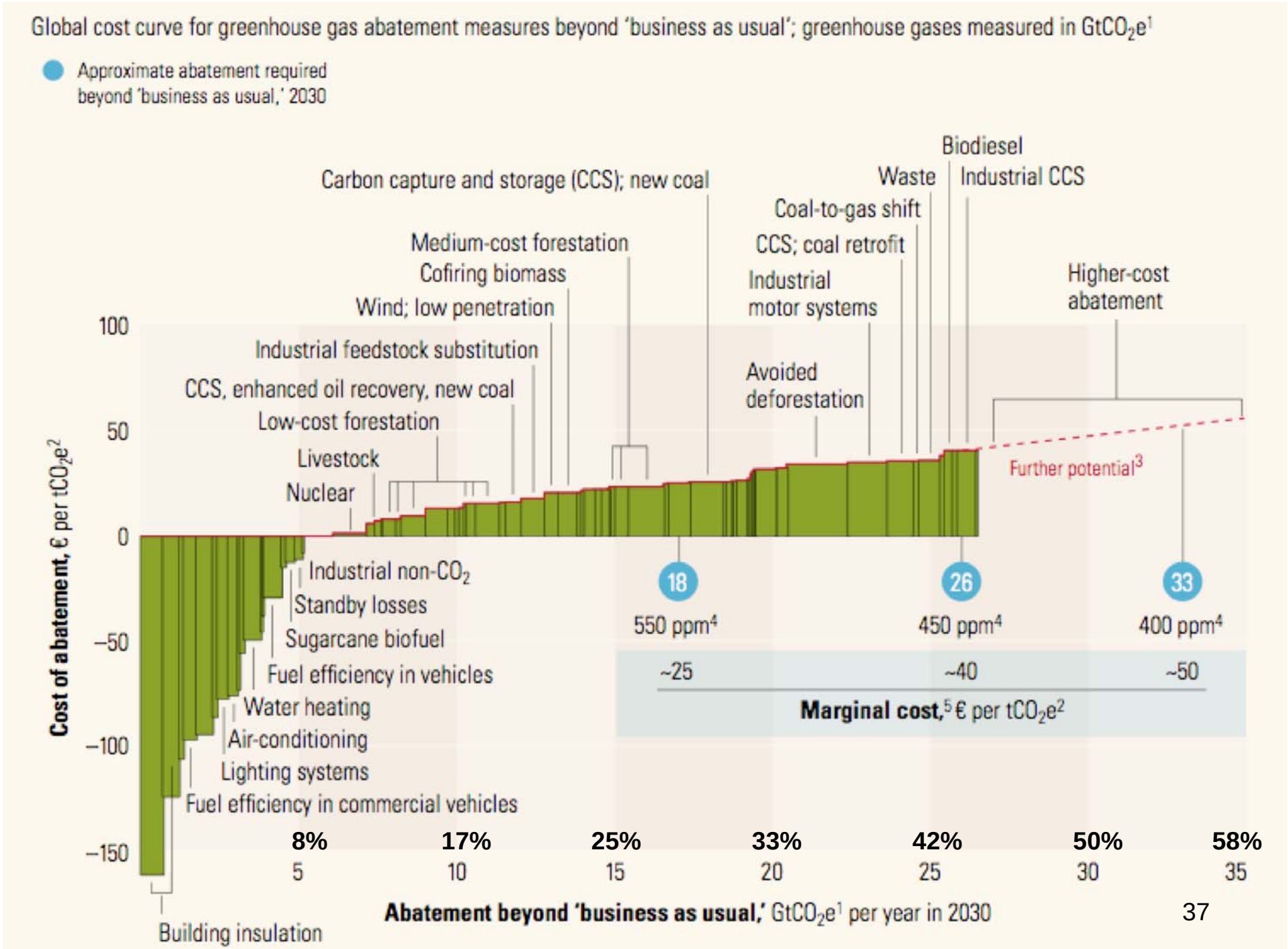
**December 12, 2007**

McKinsey&Company

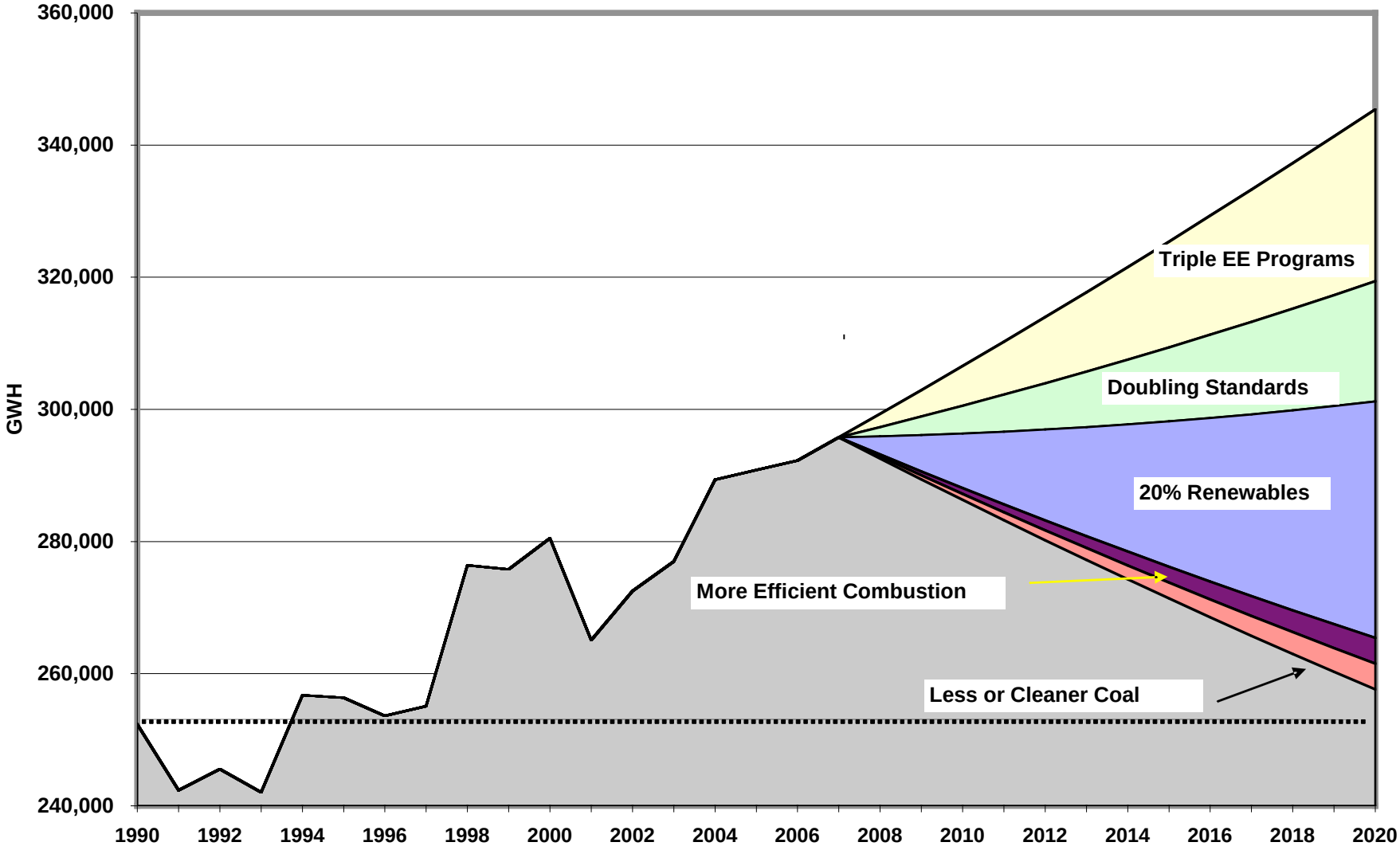
# U.S. mid-range abatement curve – 2030




Source: McKinsey analysis


Global cost curve for greenhouse gas abatement measures beyond 'business as usual'; greenhouse gases measured in $GtCO_2e^1$
Approximate abatement required beyond 'business as usual,' 2030
Biodiesel
Waste
Industrial CCS
Carbon capture and storage (CCS); new coal
Coal-to-gas shift
Medium-cost forestation
CCS; coal retrofit
Cofiring biomass
Industrial motor systems
Higher-cost abatement
Wind; low penetration
Industrial feedstock substitution
Avoided deforestation
CCS, enhanced oil recovery, new coal
Low-cost forestation
Livestock
Nuclear
Further potential3
Industrial non-$CO_2$
Standby losses
Sugarcane biofuel
Fuel efficiency in vehicles
Water heating
Air-conditioning
Lighting systems
Fuel efficiency in commercial vehicles
Building insulation
Cost of abatement, € per $tCO_2e^2$
100
50
0
−50
−100
−150
18
26
33
550 ppm4
450 ppm4
400 ppm4
~25
~40
~50
Marginal cost,5 € per $tCO_2e^2$
8%
17%
25%
33%
42%
50%
58%
5
10
15
20
25
30
35
Abatement beyond 'business as usual,' $GtCO_2e^1$ per year in 2030

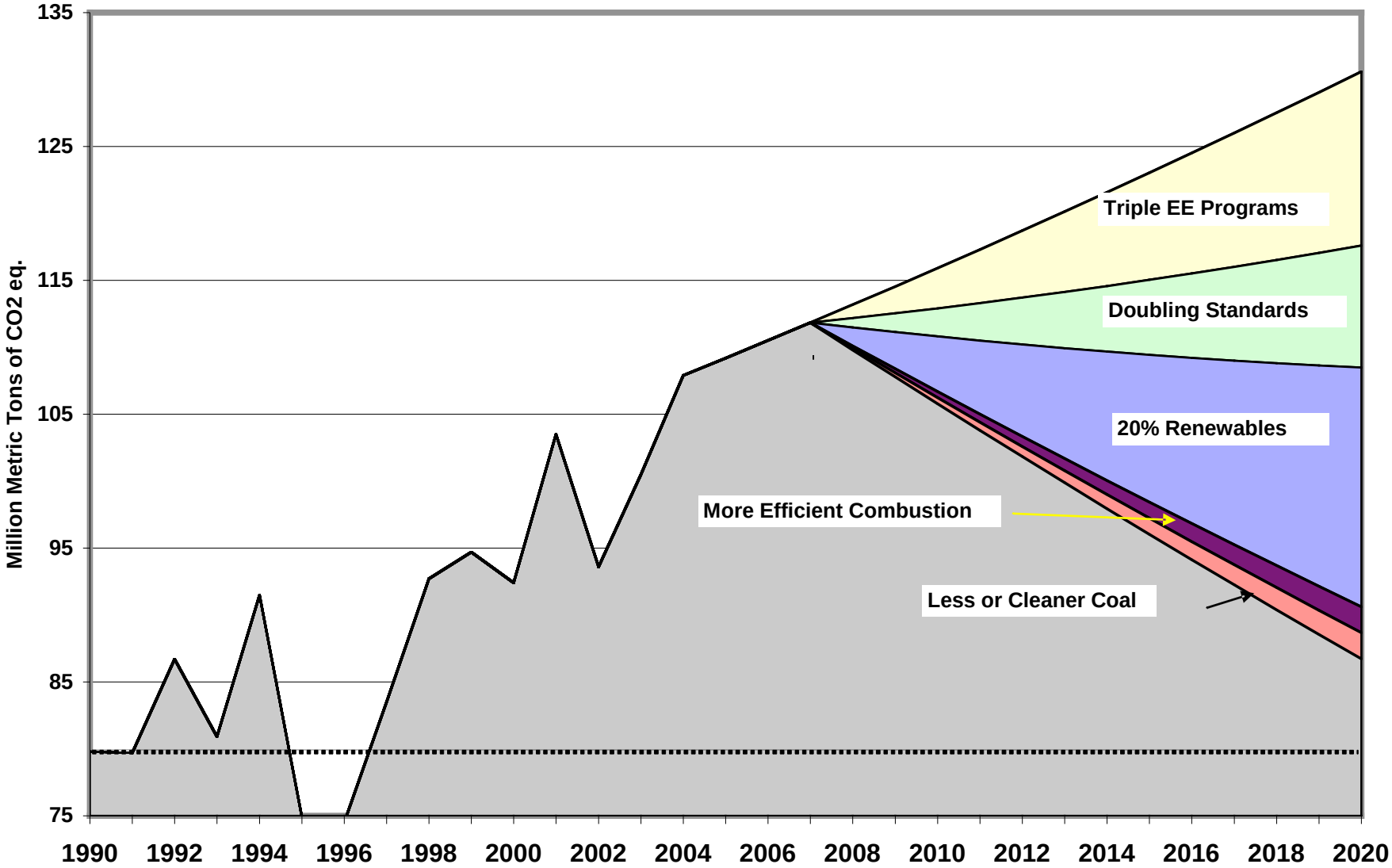
**Possible Strategies to Reduce Electricity Sector Carbon Emissions in California, ignoring ramp up times and other implementation issues -- The ELECTRICITY Perspective**






Source: Pat McAuliffe, pmcaulif@energy.state.ca.us

**Possible Strategies to Reduce Electricity Sector Carbon Emissions in California, ignoring ramp up times and other implementation issues -- The CARBON Perspective**

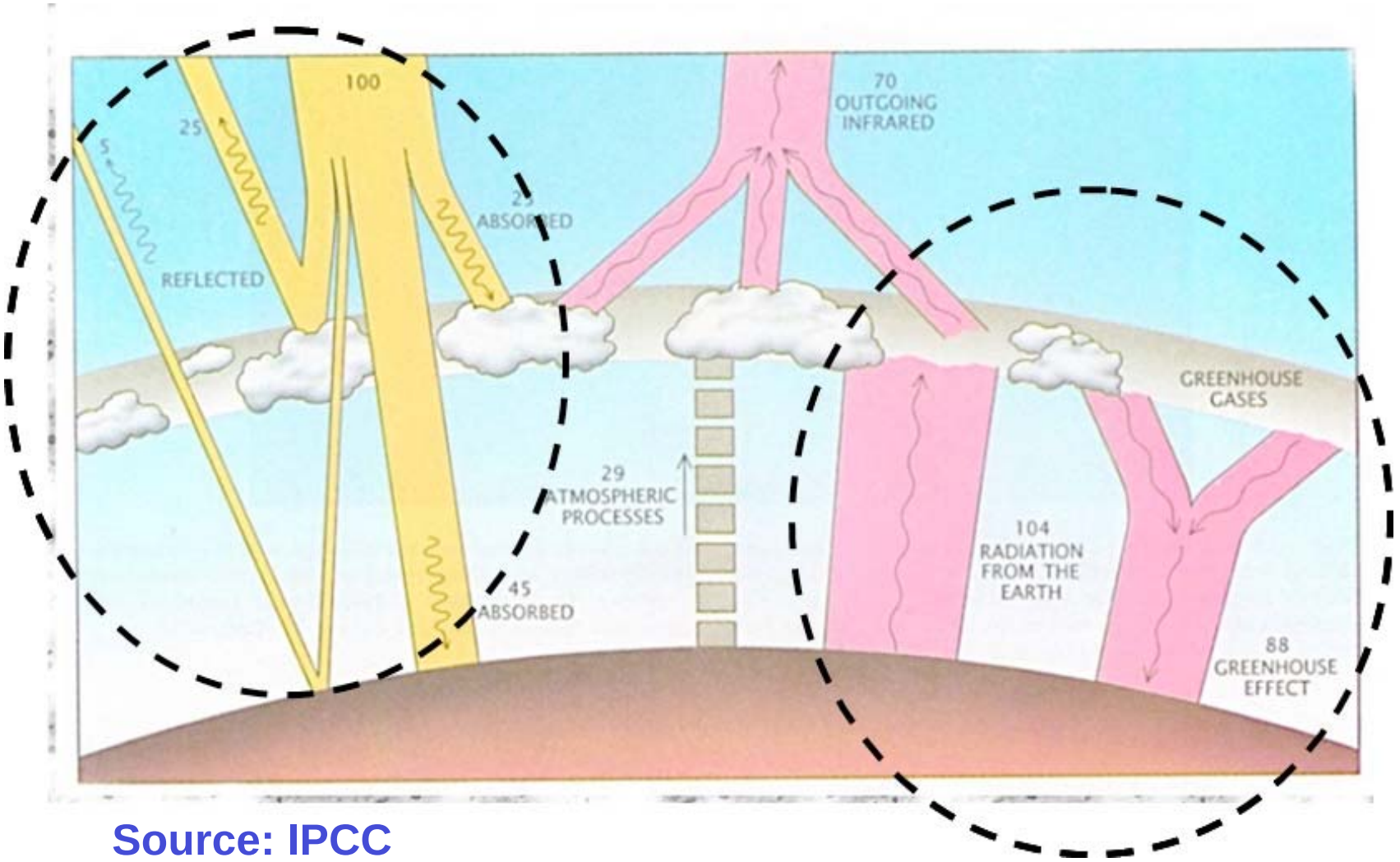





Source: Pat McAuliffe, pmcaulif@energy.state.ca.us

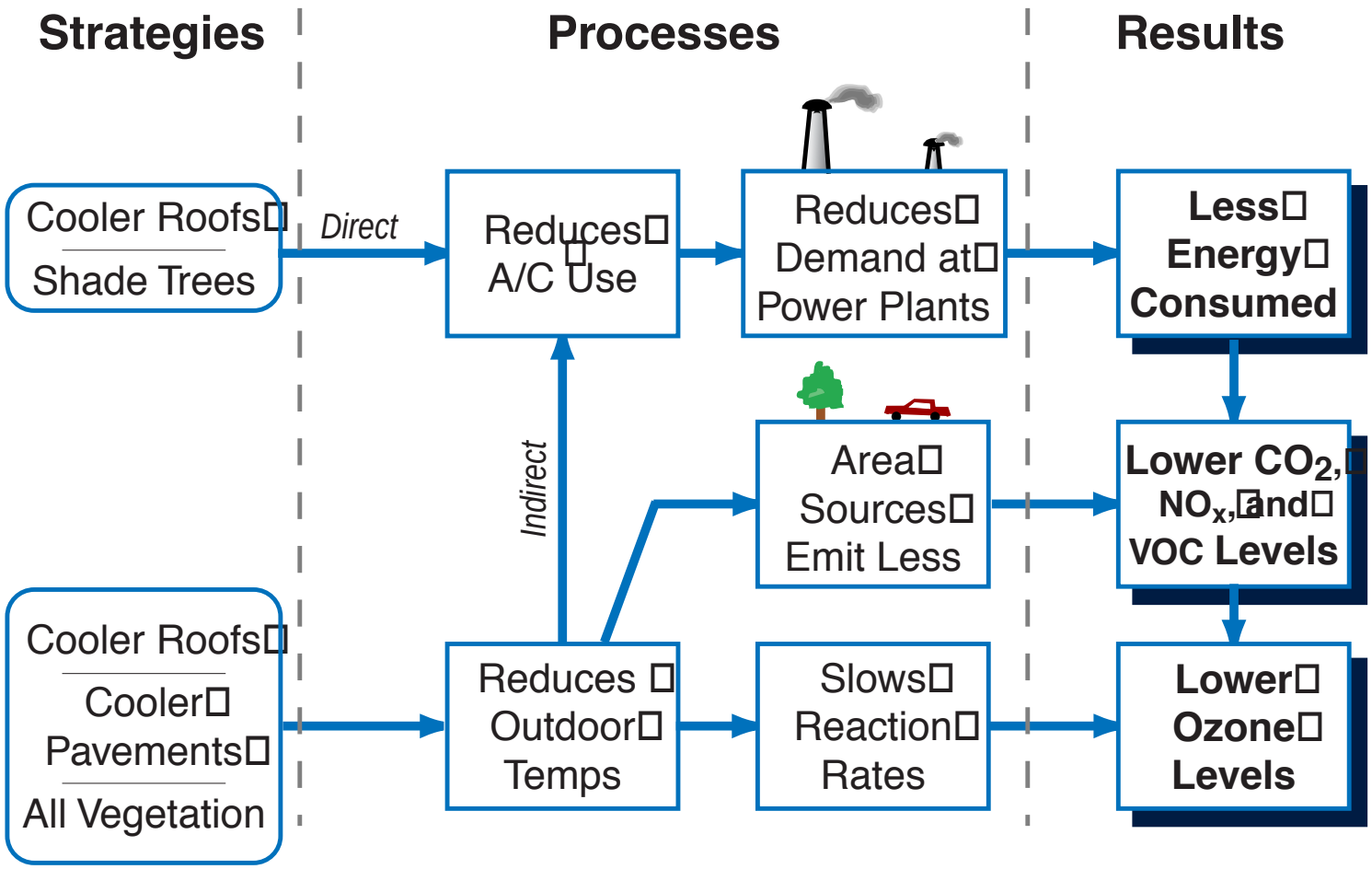
# Backup Slides on Cool Colored Roofs, Pavements and Cars

# Solar Reflective Surfaces Also Cool the Globe




Source: IPCC

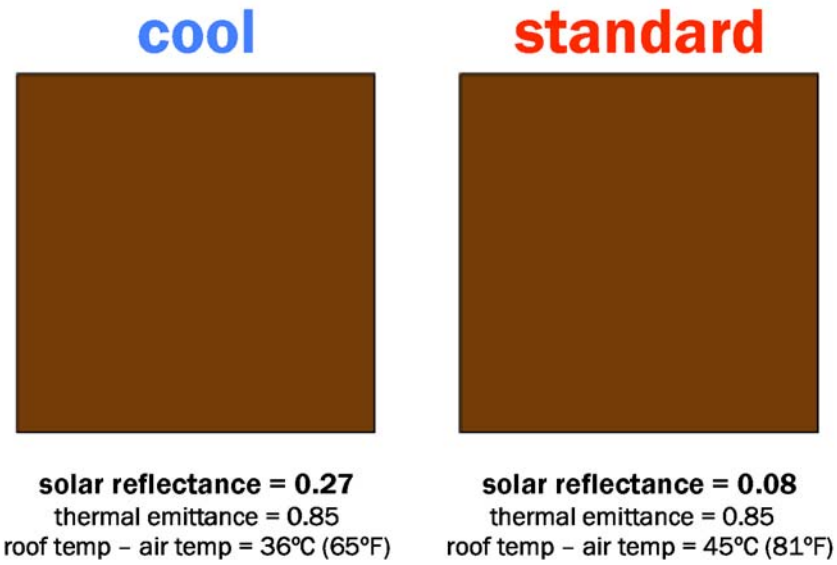
# Methodology: Energy and Air-Quality Analysis

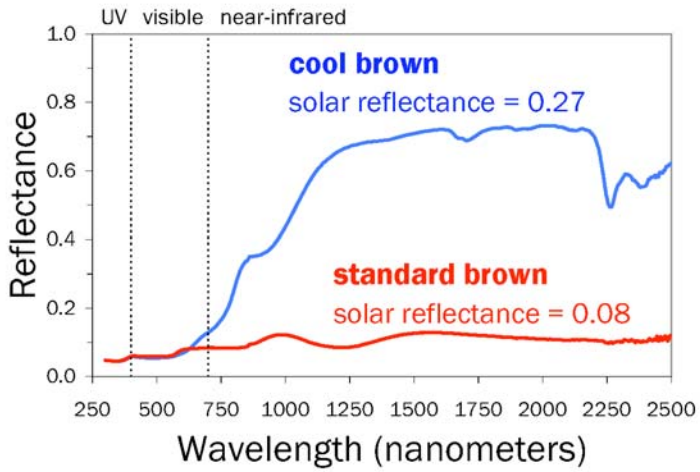


# Cool and Standard Brown Metal Roofing Panels

- Solar reflectance ~ 0.2 higher
- Afternoon surface temperature ~ 10ºC lower

Courtesy BASF Coatings



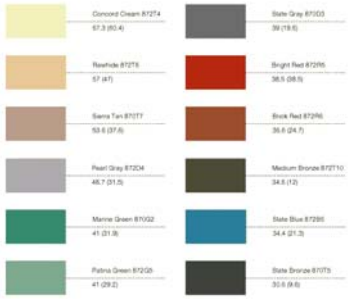
# Designing Cool Colored Roofing

| | | | | | | |
|---|---|---|---|---|---|---|
| **cool concrete tile R ≥0.40** | R=0.41 *black* | R=0.44 *blue* | R=0.44 *gray* | R=0.48 *terracotta* | R=0.46 *green* | R=0.41 *chocolate* |
| **standard concrete tile (same color)** | R=0.04 | R=0.18 | R=0.21 | R=0.33 | R=0.17 | R=0.12 |
| **solar reflectance gain =** | **+0.37** | **+0.26** | **+0.23** | **+0.15** | **+0.29** | **+0.29** |

**Courtesy American Rooftile Coatings**

**cool clay tile R ≥0.40**

**Courtesy MCA Clay Tile**



**cool metal R ≥0.30**

**Courtesy BASF Industrial Coatings**

**cool fiberglass asphalt shingle R ≥0.25**

**Courtesy Elk Corporation**

# Cool is Cool: From Cool Color Roofs to Cool Color Cars and Cool Jackets




- Toyota experiment (surface temperature 10K cooler)
- Ford is also working on the technology

**Courtesy: BMW (http://www.ips-innovations.com/solar_reflective_clothing.htm)**

# Cool Paving Materials:

| *Concrete* | **(a)** Unexposed | **(b)** Weathered | **(c)** Weathered, wetted | **(d)** Soiled | **(e)** Abraded | **(f)** Formed |
|---|---|---|---|---|---|---|
| **C1:S1:R2** gray cement/ riverbed sand/ granite rock | ρ=0.44 | ρ=0.34 | ρ=0.14 | ρ=0.43 | ρ=0.24 | ρ=0.25 |

# Reflective Pavements are Cooler

- **Fresh asphalt**

**Albedo: 0.05**
**Temperature: 123°F**

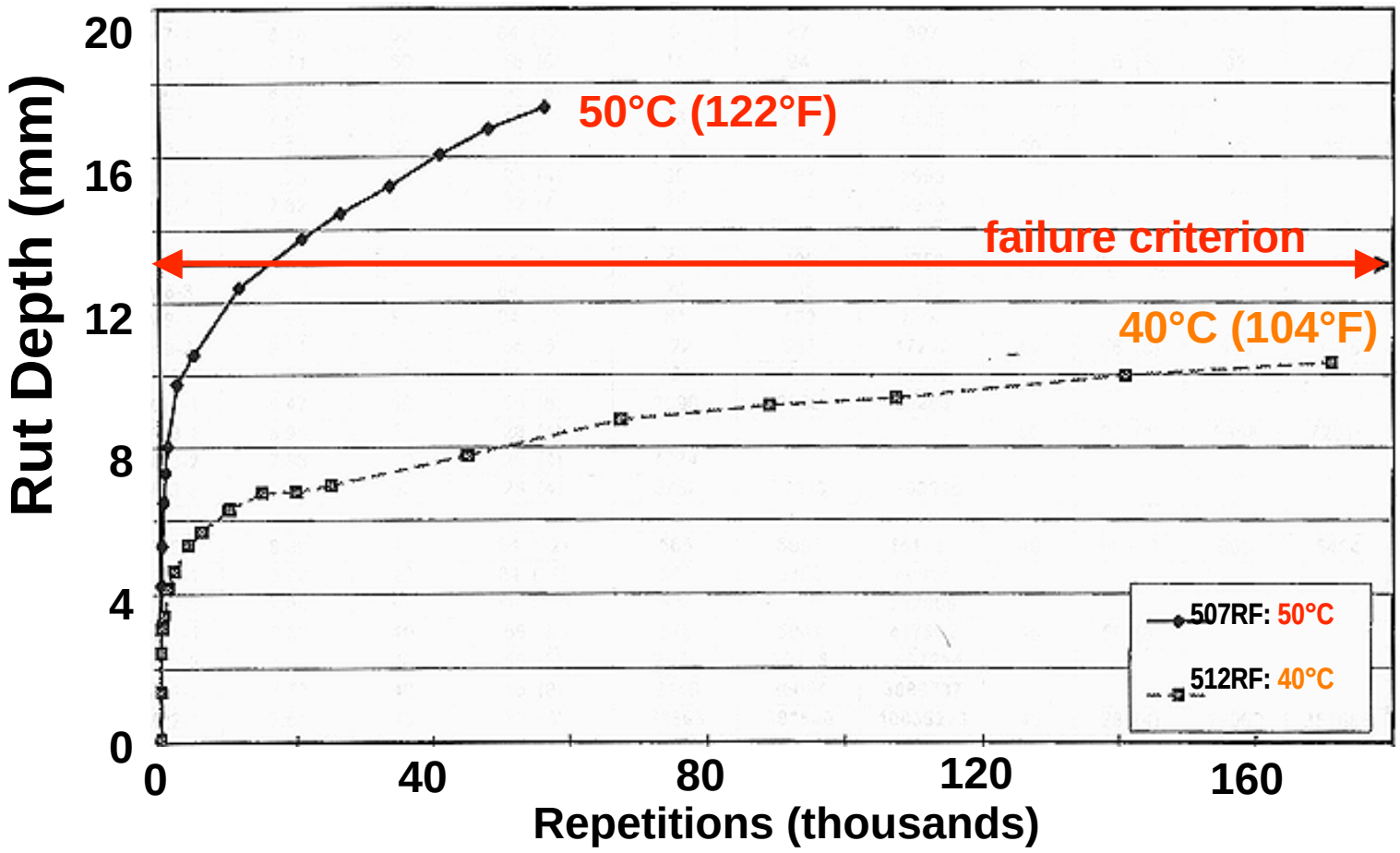
- **Aged asphalt**

**Albedo: 0.15**
**Temperature: 115°F**

- **Prototype asphalt coating**

**Albedo: 0.51**
**Temperature: 88°F**

# Temperature Effect on Rutting

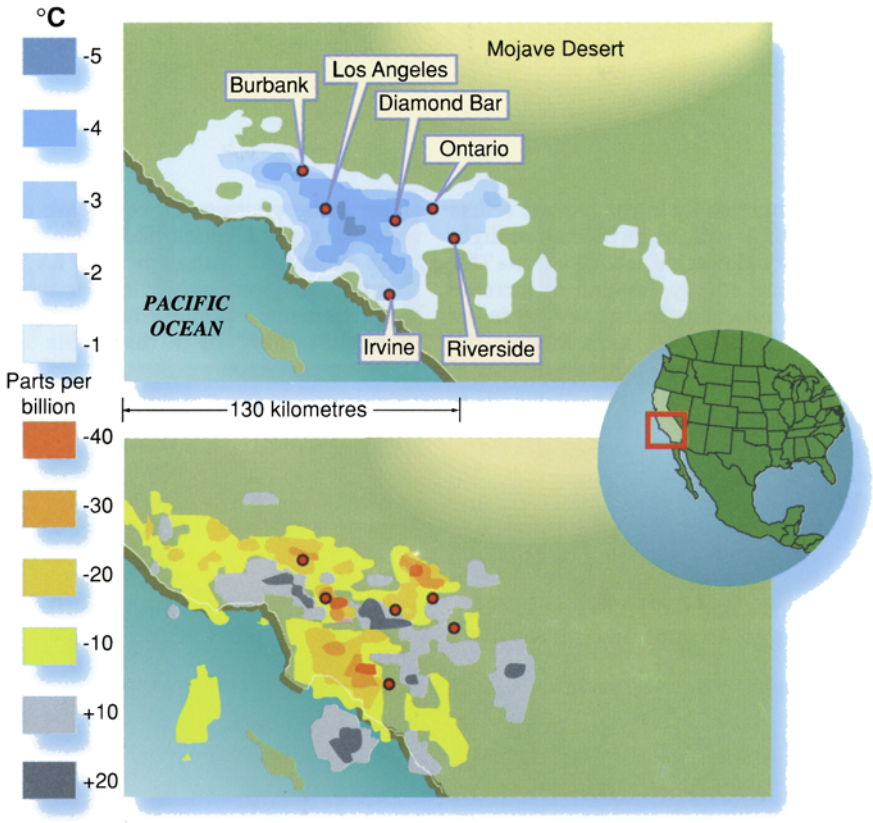



*Source: Dr. John Harvey, UC B Civil Engineering, Inst. Transpo. Studies*

# Simulated Meteorology and Air-quality Impacts in LA

Temperature Change

Ozone Concentration Change



# Potential Savings in LA

- **Savings for Los Angeles**
  - Direct, $100M/year
  - Indirect, $70M/year
  - Smog, $360M/year

- **Estimate of national savings: $5B/year**